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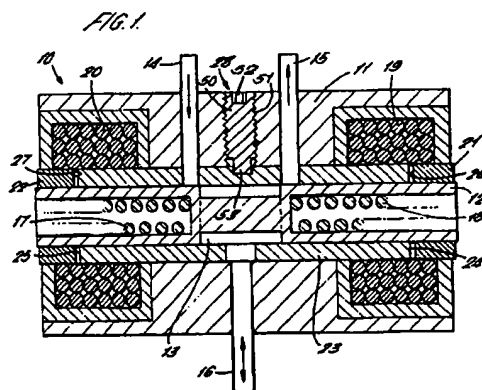
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**WO 2002/046582 A2**      **JP 580032985 A**  
**JP 110257504 A**      **JP 080049659 A**  
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 INT CL<sup>7</sup> F01L, F04B, F15B, F16K  
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(54) Abstract Title: **An electrically operated hydraulic fluid control valve**

(57) The invention relates to an electrically operated valve 10, which has a valve housing 11, a spool 12, a first fluid conduit 14 connecting the valve 10 with a source of pressurised fluid, a second fluid conduit 15 connecting the valve 10 with a reservoir of fluid, and a third conduit 16 in communication with valve 10 which delivers fluid to or receives fluid from apparatus which uses the hydraulic fluid flow controlled by the valve 10. The spool 12 is biased to a rest position by a pair of opposed springs 17 and 18 and in the rest position closes off the first 14 and second 15 fluid conduits. A first electric coil 19 associated with a first end of the spool 12 when activated displaces the spool 12 to open the first fluid conduit 14. A second electric coil 20 associated with a second end of the spool 12 when activated displaces the spool 12 to open the second fluid conduit 15.



GB 2 391 288 A

AN ELECTRICALLY OPERATED VALVE FOR CONTROLLING  
FLOW OF HYDRAULIC FLUID

5 The present invention relates to an electrically  
operated valve for controlling flow of hydraulic  
fluid.

10 The present invention will be discussed with  
particular reference to the use of valves for  
controlling flow of hydraulic fluid to actuators  
attached to engine valves of an internal combustion  
engine. It has often been suggested in the past that  
in an internal combustion engine a mechanical cam  
shaft could be replaced by a series of hydraulic  
15 actuators which would open and close the engine valve.  
The hydraulic actuators are controlled by controlling  
the flow of hydraulic fluid to them. Various  
different arrangements of valves have been proposed  
for the control of hydraulic fluid. However, there is  
20 still a need for a simple and cost-effective valve  
arrangement and this issue is addressed by the present  
invention.

25 The present invention provides an electrically  
operated valve for controlling flow of hydraulic fluid  
comprising:

- a valve housing;
- a spool slidable in a spool chamber in the valve  
housing;
- 30 a first fluid conduit extending through the valve  
housing for connecting the spool chamber with a source  
of pressurised fluid;
- a second fluid conduit extending through the  
valve housing for connecting the spool chamber with a  
35 reservoir of fluid; and

a third fluid conduit in communication with the spool chamber which delivers fluid to or receives fluid from apparatus which uses the hydraulic fluid flow controlled by the valve; wherein:

5       the spool is biased to a rest position by a pair of opposed springs;

10       the spool in the rest position thereof closes off the first and second fluid conduits from the spool chamber and thereby prevents flow of fluid to and from the third fluid conduit;

15       the valve has a first electric coil which surrounds a first end of the spool and which can be activated to displace the spool from the rest position thereof to open the first fluid conduit to the spool chamber, whilst keeping closed the second fluid conduit, and thereby to allow pressurised fluid to flow from the first fluid conduit to the third fluid conduit; and

20       the valve has a second electric coil which surrounds a second end of the spool and which can be activated to displace the spool from the rest position thereof to open the second fluid conduit to the spool chamber, whilst keeping closed the first fluid conduit, and thereby to allow fluid to flow from the third fluid conduit to the second fluid conduit.

A preferred embodiment of the present invention will now be described with reference to the accompanying drawings in which:-

30       Figure 1 is a schematic illustration of an electrically operated valve for controlling flow of hydraulic fluid according to a preferred embodiment of the present invention;

35       Figure 2 is a schematic illustration of how the valve of Figure 1 could be used in an internal combustion engine.

Turning first to Figure 1 there can be seen an electrically operated valve 10 controlling the flow of hydraulic fluid therethrough. The valve 10 comprises a valve housing 11 having slidable therein a spool 12,  
5 the spool being slidable in a spool chamber 13 provided in the valve housing 11.

A first fluid conduit 14 extends through the valve housing 11 and connects the spool chamber 13  
10 with a source of pressure.

A second fluid conduit 15 extends through the valve housing 11 and connects the spool chamber 13 with a return line for returning hydraulic fluid to a  
15 reservoir.

A third fluid conduit 16 connects the valve 10 to whatever apparatus receives the flow of hydraulic fluid controlled by the valve 10.  
20

In Figure 1 there can be seen two opposed springs 17 and 18 which together act to centre a spool 12. When the spool 12 is centred both springs will still be compressed and will still each apply a force on the  
25 spool 12, but the forces applied by the two springs 17 and 18 will be equal and opposite.

Two electric coils 19 and 20 surround the ends of the spool 12. Surrounding each end of the spool 12  
30 there is provided armature 21 and 22.

The spool 12 is surrounded by a sleeve 23. This sleeve 23 has two annular end surfaces 24 and 25. The annular end surface 24 faces an annular end surface 26  
35 of the armature 21. The annular surface 25 faces an

annular surface 27 of the armature 22.

5       When the electric coil 20 is actuated then the magnetic circuit acts to draw the armature 22 into engagement with the annular surface 25 of the sleeve 23. Thus, the spool valve is moved to the right of its position shown in Figure 1, against the biasing force of the spring 18.

10       When the electric coil 19 is activated then the magnetic field generated by the coil acts to draw the armature 21 towards the annular surface of the sleeve 23 and thereby move the spool 12 to the left of its position in Figure 1, against the biasing force of  
15       the spring 17.

      With the spool 12 positioned as shown in Figure 1 the pressure line 14 and the return line 15 are both sealed off from the spool chamber 13 and therefore no  
20       hydraulic fluid can flow to or from the fluid conduit 16.

      When the spool 12 is moved to the right of its position in Figure 1 then the fluid conduit 16 is  
25       connected via the spool chamber 13 with the return line 15 and therefore fluid can flow from the line 16 through the spool chamber 13 to the fluid conduit 15 and thereby to a reservoir of hydraulic fluid.

30       When the spool 12 is moved to the left of its position in Figure 1 then the conduit 14 is opened to the spool chamber 13 whilst the conduit 15 remains sealed. Thus, pressurised fluid can flow through the conduit 14 to the conduit 16 via the spool chamber 13.

35

The fluid conduit 16 is permanently open to the spool chamber 13.

In Figure 1 there can be seen a null adjust  
5 mechanism 28. This comprises an externally threaded  
rotatable screw 50 provided in a threaded bore 51 in  
the valve housing 11. A hexagonal socket 52 is  
provided at the tip of the screw 50 and can be engaged  
and rotated by an Allen key. An eccentric cam 53  
10 extends downwardly from the screw 50 and acts on a  
reaction surface provided on the sleeve 23. On  
rotating the cam 53 it is possible to slide the sleeve  
23 within the valve housing 11. This can be done to  
ensure that when the two electric coils 19, 20 are  
15 deactivated and the spool 12 brought to a central  
position by the two springs 17 and 18, then the ports  
in the sleeve 23 via which the pressure line 14 and  
the return line 15 open onto the spool chamber 13 are  
both closed off by the spool 12.

20 By having a high pre-load applied on the spool 12  
in its resting position by both the spring 17 and the  
spring 18, with the forces applied by the springs  
cancelled out by each other, it is possible to set a  
25 low spring rate and to determine how much force must  
be applied to move the spool valve 12 from its  
centralised position. This feature allows the valve  
to be used easily as a metering valve, because the  
current flowing through each of the electrical coils  
30 20 or 21 can be adjusted to give a variable  
displacement of the valve spool 12, a variable degree  
of opening of the ports in the sleeve 23 and therefore  
a variable rate of flow through the valve 10.  
However, if wished, the valve 10 could operate as a  
35 switching valve, moving only between extreme positions

by applying high value square-wave signals to the coils 19 and 20.

5 Moving now to Figure 2, the valve 10 can be seen represented schematically. The pressure line 14 is shown connected to a pump 30 and the return line 15 is shown connected to a reservoir 31. The line 16 is shown connected to an actuator 32. The actuator 32 comprises a piston 33 movable in a cylinder defined by  
10 a sleeve 34. Piston 33 and the sleeve 34 define together a variable volume chamber 35 which receives hydraulic fluid via the line 16.

15 A position sensor 36 is built into the sleeve 34 and provides a feed back signal to an electronic controller 37. The electronic controller 37 uses the feedback signal along with other received parameters to provide a control signal which is relayed to the valve 10. As explained before, the control signal will  
20 be used to apply a current to one of the two coils 20 and 19.

When the actuator 32 is connected to the pump 30 via the valve 10 then the piston 33 is caused to move  
25 downwardly and to open an engine valve 40 of an internal combustion engine, (e.g. an inlet or an exhaust valve).

30 When the actuator 32 is connected to the reservoir 31 via the valve 10 then a valve spring 41 acting on the engine valve 40 can force the piston 33 to reduce in volume the chamber defined between piston 33 and sleeve 34, with the dispelled fluid being relayed via the valve 10 to the reservoir 31.

35

The rate of opening of the valve 40 and the rate of closing of the valve 40 can be controlled by controlling the rate of flow of fluid through the valve 10.

5

The electronic controller 37 is part of a closed-loop feedback system which controls the position of the engine valve 40. The electronic controller 37 will send a demand signal to the valve 10 in the expectation that this will result in a position (and perhaps a rate of change of position) of the piston 33 and therefore the engine valve 40. The displacement transducer 36 will provide a signal which can be used to generate an error signal so that the electronic controller 37 can adjust the control signal it sends to the valve 10.

The use of feedback signal is important since the provision of a closed loop feedback system can provide for adaptive control, with the electronic controller making adjustments during the life of an engine to account for wear of components in the engine.

20



CLAIMS

1. An electrically operated valve for controlling flow of hydraulic fluid comprising:
  - 5 a valve housing;  
a spool slidable in a spool chamber in the valve housing;  
a first fluid conduit extending through the valve housing for connecting the spool chamber with a source of pressurised fluid;  
10 a second fluid conduit extending through the valve housing for connecting the spool chamber with a reservoir of fluid; and  
a third fluid conduit in communication with the spool chamber which delivers fluid to or receives fluid from apparatus which uses the hydraulic fluid flow controlled by the valve; wherein:  
the spool is biased to a rest position by a pair of opposed springs;  
20 the spool in the rest position thereof closes off the first and second fluid conduits from the spool chamber and thereby prevents flow of fluid to and from the third fluid conduit;  
the valve has a first electric coil which  
25 surrounds a first end of the spool and which can be activated to displace the spool from the rest position thereof to open the first fluid conduit to the spool chamber, whilst keeping closed the second fluid conduit, and thereby to allow pressurised fluid to flow from the first fluid conduit to the third fluid  
30 conduit; and  
the valve has a second electric coil which surrounds a second end of the spool and which can be activated to displace the spool from the rest position  
35 thereof to open the second fluid conduit to the spool

chamber, whilst keeping closed the first fluid conduit, and thereby to allow fluid to flow from the third fluid conduit to the second fluid conduit.

5     2.   An electrically operated valve as claimed in claim 1 wherein the pair of opposed springs each apply a force on the spool when the spool valve is in the rest position thereof.

10    3.   An electrically operated valve as claimed in claim 1 or claim 2 wherein a sleeve surrounds the spool and defines the spool chamber in which the spool is slidable, the sleeve having a first port through which the first fluid conduit communicates with the  
15    spool chamber, a second port through which the second fluid conduit communicates with the spool chamber and a third port through which the third fluid conduit communicates with the spool chamber, and wherein the valve has an adjustment mechanism for sliding the  
20    sleeve relative to the valve housing.

4.   An electrically operated valve as claimed in claim 3 wherein the adjustment mechanism comprises a rotatable cam which engages a reaction surface  
25    provided on the sleeve.

5.   An electrically operated valve as claimed in any one of the preceding claims wherein the spool has mounted thereon an armature surrounding the first end  
30    of the spool and displaceable with the first electric coil and the spool has mounted thereon an armature surrounding the second end of the spool and displaceable within the second electric oil.

35    6.   A method of operating the electrically operated

valve claimed in any one of the preceding claims, the method comprising:

- 5       selecting between the first and second coils and activating the first electric coil when pressurised fluid is to be relayed on to the apparatus using the hydraulic fluid flow and activating the second electric coil when fluid is to be returned from the apparatus using the hydraulic fluid flow back to the reservoir; and
- 10       controlling the current through and/or voltage across each electric coil when activated in order to control rate of flow of fluid through the valve.
7.    An engine valve operating system comprising:
- 15       an actuator which acts on an engine valve and can be extended to open the engine valve and retracted to allow the engine valve to close under the action of an engine valve spring;
- 20       an electrically operated valve as claimed in any one of the preceding claims controlling flow of hydraulic fluid to and from the actuator; and
- an electronic controller for controlling the actuator.
- 25    8.   An engine valve operating system as claimed in claim 7 wherein:
- the actuator comprises a piston movable in a cylinder;
- 30       the system comprises additionally a position transducer which produces a position signal indicative of the position of the piston; and
- the electronic controller uses the position signal to generate an error signal used in closed loop control of the actuator.

9. An electrically operated valve for controlling flow of hydraulic fluid substantially as hereinbefore described with reference to and as shown in the accompanying Figure 1.

5

10. An engine valve operating system substantially as hereinbefore described with reference to and as shown in the accompanying Figure 3.

10

**Amendments to the claims have been filed as follows**

## CLAIMS

1. An electrically operated valve for controlling flow of hydraulic fluid comprising:
- 5 a valve housing;  
a spool slidable in a spool chamber in the valve housing;  
a first fluid conduit extending through the valve housing for connecting the spool chamber with a source of pressurised fluid;
- 10 a second fluid conduit extending through the valve housing for connecting the spool chamber with a reservoir of fluid; and  
a third fluid conduit in communication with the spool chamber which delivers fluid to or receives fluid from apparatus which uses the hydraulic fluid flow controlled by the valve; wherein:
- 15 the spool is biased to a rest position by a pair of opposed springs;  
the spool in the rest position thereof closes off the first and second fluid conduits from the spool chamber and thereby prevents flow of fluid to and from the third fluid conduit;
- 20 the valve has a first electric coil which surrounds a first end of the spool and which can be activated to displace the spool from the rest position thereof to open the first fluid conduit to the spool chamber, whilst keeping closed the second fluid conduit, and thereby to allow pressurised fluid to flow from the first fluid conduit to the third fluid conduit; and
- 25 the valve has a second electric coil which surrounds a second end of the spool and which can be activated to displace the spool from the rest position thereof to open the second fluid conduit to the spool
- 30

chamber, whilst keeping closed the first fluid conduit, and thereby to allow fluid to flow from the third fluid conduit to the second fluid conduit.

- 5      2.    An electrically operated valve as claimed in claim 1 wherein the pair of opposed springs each apply a force on the spool when the spool valve is in the rest position thereof.
- 10     3.    An electrically operated valve as claimed in claim 1 or claim 2 wherein a sleeve surrounds the spool and defines the spool chamber in which the spool is slidable, the sleeve having a first port through which the first fluid conduit communicates with the  
15     spool chamber, a second port through which the second fluid conduit communicates with the spool chamber and a third port through which the third fluid conduit communicates with the spool chamber, and wherein the  
20     valve has an adjustment mechanism for sliding the sleeve relative to the valve housing.
- 25     4.    An electrically operated valve as claimed in claim 3 wherein the adjustment mechanism comprises a rotatable cam which engages a reaction surface  
provided on the sleeve.
- 30     5.    An electrically operated valve as claimed in any one of the preceding claims wherein the spool has mounted thereon an armature surrounding the first end  
of the spool and displaceable with the first electric  
coil and the spool has mounted thereon an armature  
surrounding the second end of the spool and  
displaceable within the second electric coil.
- 35     6.    A method of operating the electrically operated

valve claimed in any one of the preceding claims, the method comprising:

5 selecting between the first and second coils and activating the first electric coil when pressurised fluid is to be relayed on to the apparatus using the hydraulic fluid flow and activating the second electric coil when fluid is to be returned from the apparatus using the hydraulic fluid flow back to the reservoir; and

10 controlling the current through and/or voltage across each electric coil when activated in order to control rate of flow of fluid through the valve.

7. An engine valve operating system comprising:

15 an actuator which acts on an engine valve and can be extended to open the engine valve and retracted to allow the engine valve to close under the action of an engine valve spring;

20 an electrically operated valve as claimed in any one of the preceding claims controlling flow of hydraulic fluid to and from the actuator; and

an electronic controller for controlling the actuator.

25 8. An engine valve operating system as claimed in claim 7 wherein:

the actuator comprises a piston movable in a cylinder;

30 the system comprises additionally a position transducer which produces a position signal indicative of the position of the piston; and

the electronic controller uses the position signal to generate an error signal used in closed loop control of the actuator.

9. An electrically operated valve for controlling flow of hydraulic fluid substantially as hereinbefore described with reference to and as shown in the accompanying Figure 1.

5

10. An engine valve operating system substantially as hereinbefore described with reference to and as shown in the accompanying Figure 3.

10





INVESTOR IN PEOPLE

Application No: GB 0217642.8  
Claims searched: 1 to 3, 5, 7 & 8

16 Examiner: Gareth Bond  
Date of search: 27 February 2003

## Patents Act 1977 : Search Report under Section 17

### Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance	
Y	1,2,3, 5,7,8	JP110257504	(Yuken Kogyo Co Ltd.) 1998-03-09 WPI abstract accession number 1999-587387 [50] See figure 2 and the abstract.
Y	1,2,3, 5,7,8	US6067946	(Cummins Engine Co Inc.) See figure 17 items 27, 37, 42, 50 and 52 along with column 2 lines 24 to 27, column 6 lines 58 to 67 and column 7 lines 13 to 31 for an example of a pressure control means and a suitable engine valve operating system.
Y	1,2,3, 5,7	WO0246582	(Sturman Industries, Inc) See figures 1 & 2 along with paragraph 25 for an example of a suitable control valve and engine valve operating system.
Y	3	JP580032985	(Hitachi Construction Machinery) See figure 5 items 32 and 33 along with the abstract for an example of a suitable adjustable sleeve.
Y	3	JP080049659	(Hitachi Construction Machinery) 1994-08-05 WPI abstract accession number 1996-167952 [17] See figure 1 items 7 and 8 along with the abstract for an example of a suitable adjustable sleeve.
A		JP2002195425	(Kayaba Industry Co Ltd.) 2000-12-28 WPI abstract accession number 2002-570935 [61] See figure 2 and the abstract, where 56, 57 and 58 are taken as the three conduits of claim 1.

### Categories:

X Document indicating lack of novelty or inventive step	A Document indicating technological background and/or state of the art.
Y Document indicating lack of inventive step if combined with one or more other documents of same category.	P Document published on or after the declared priority date but before the filing date of this invention.
& Member of the same patent family	E Patent document published on or after, but with priority date earlier than, the filing date of this application.



**Application No:** GB 0217642.8  
**Claims searched:** 1 to 3, 5, 7 & 8

**Examiner:** Gareth Bond  
**Date of search:** 27 February 2003

**Field of Search:**

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC<sup>v</sup>:

F2V, F1B

Worldwide search of patent documents classified in the following areas of the IPC<sup>7</sup>:

F16K, F15B, F01L, F04B.

The following online and other databases have been used in the preparation of this search report :

EPODOC, JAPIO, WPI, TXTE

FIG. 1

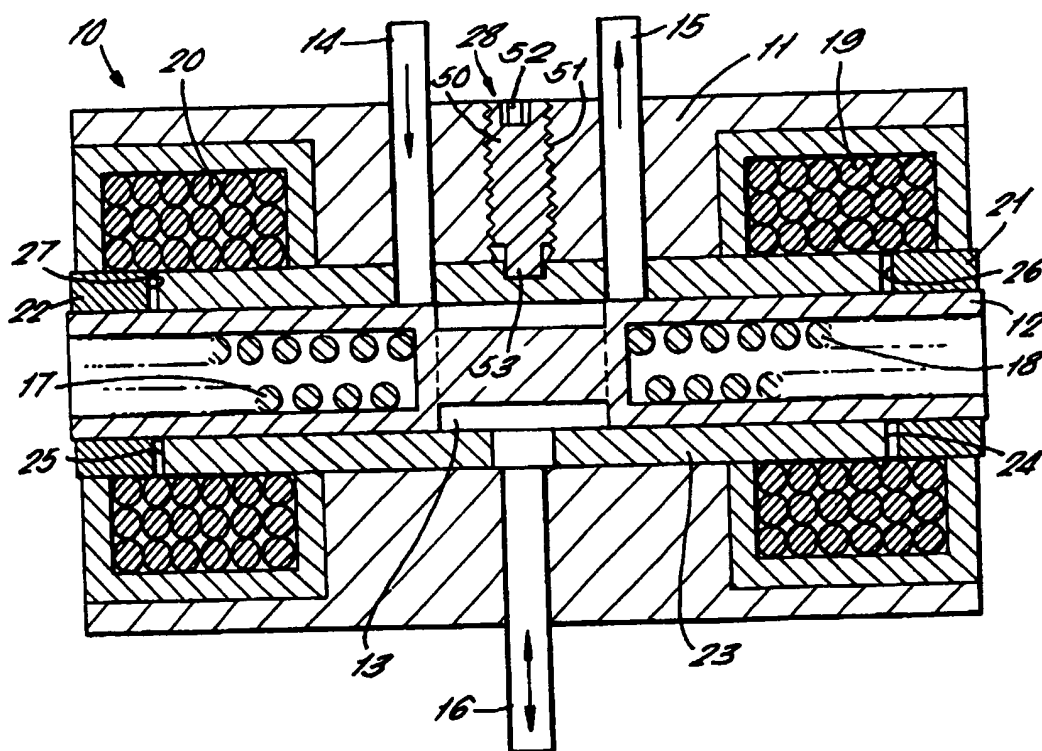


FIG. 2.

